T··Mobile·

August 24, 2010

EX PARTE NOTICE

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Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW, Room TW-A325
Washington, D.C. 20554

Re: *700 MHz Interoperable Broadband Public Safety Network*
WT Docket No. 06-150, PS Docket No. 06-229,
GN Docket Nos. 09-47, 09-51, 09-137, RM Docket No. 11592

Dear Ms. Dortch:

T-Mobile USA, Inc. ("T-Mobile") submits for inclusion in the above-captioned dockets the enclosed white paper, *Technical Analysis of the Proposed 700 MHz D-Block Action* ("*White Paper*"), prepared by Professor Dennis Roberson, of Roberson and Associates, LLC. Prof. Roberson is a former Chief Technology Officer ("CTO") of Motorola Inc. and has extensive experience with public safety technology and communications. He is currently a Vice Provost and Research Professor at the Illinois Institute of Technology in Chicago, Illinois.

In the White Paper, Prof. Roberson and his staff performed a comprehensive technical analysis of the record in these proceedings, and information available in the broader technical community regarding the public safety broadband networks outlined in the Commission's National Broadband Plan. The White Paper concludes that incentive partnerships with competitive commercial carriers in the 700 MHz D block would enable public safety to build broadband networks with sufficient capacity without harmful interference. As summarized below, public safety broadband networks using a low-site architecture, LTE technology, and existing spectrum in the 700 MHz and 4.9 GHz bands can meet the day-to-day needs of public safety. Roaming with priority access on the D Block and other commercial LTE networks can augment public safety capacity during major emergencies and disasters.

Public Safety Broadband Needs and Spectrum Capacity: The capacity provided by a dense 10 MHz LTE network using the 700 MHz Public Safety Broadband ("PSBB") spectrum is sufficient on a system and sector-cell basis to meet current public safety broadband needs. High-quality video streams can be provided by this 700 MHz LTE network over a wide geographical area and commercially available technologies exist to provide increased throughput at cell-edges. Additionally, 50 MHz of broadband spectrum from the 4.9 GHz public safety band can be used in a coordinated manner to further increase capacity at incident scenes.

Transitioning 700 MHz Narrowband to Broadband: Portions of the 12 MHz of 700 MHz spectrum dedicated to public safety narrowband voice can be transitioned, over time, to broadband.[1] This transition can occur without sacrificing interoperability among public safety narrowband voice networks by leaving portions of the spectrum for narrowband voice interoperability. Additionally, the White Paper analyzes how public safety is already receiving significant increases in narrowband voice capacity due to an FCC mandated 6.25 kHz conversion in the VHF and UHF bands and the reconfiguration of the 800 MHz band. These factors suggest the Commission, in conjunction with public safety, should engage in a thorough analysis about the future repurposing of portions of the 700 MHz public safety narrowband spectrum allocation.

Using Commercial 700 MHz D Block Networks for Public Safety: The LTE standard allows for the design of a commercial network in the 700 MHz D Block that can effectively provide public safety users with additional capacity during major emergencies and disaster situations. LTE provides a robust priority access system for public safety users to achieve any desired priority level – including the insertion of public safety packet streams onto otherwise fully loaded traffic channels – on commercial D Block networks. This is possible because of the packetized nature of communications on LTE networks and the built-in mechanisms within the LTE access channel protocols to selectively inhibit service requests from low priority users during periods of heavy demand. A commercial D Block LTE access channel will be prioritized to ensure access to public safety users. Finally, LTE provides flexible, cost effective, and dynamic approaches for apportioning traffic between a 700 MHz dedicated public safety broadband network and a commercial D Block network.

Limited Interference Risks: Any potential for adjacent channel interference between the commercial D Block and the PSBB spectrum can be readily avoided if both systems are based on the LTE standard and use similar system design guidelines with comparable cell sizes. LTE, like most modern broadband technologies, is designed to allow networks to operate on adjacent spectrum without causing harmful interference. The ideal situation as described in the National Broadband Plan, FCC White Paper, and other sources is for the dedicated public safety network base sites to share infrastructure and co-locate when possible with the commercial D Block sites. Co-location of public safety and commercial base site equipment is not uncommon today and would expedite public safety network deployment. However, co-location is not a prerequisite to avoiding harmful interference between D Block and public safety networks. Finally, the potential for interference generated within user device transceivers with integral GPS receivers can be avoided with a number of well established methods. This GPS interference issue should not be a decision factor in the allocation of the D Block for commercial use.

[1] Public safety has a total of 24 MHz in the 700 MHz band. 12 MHz is dedicated to narrowband voice and 10 MHz is dedicated to broadband. Public safety has assigned a 2 MHz guard band in-between its narrowband and broadband operations.

Pursuant to Section 1.1206(b) of the Commission's rules, an electronic copy of this letter is being filed with the office of the Secretary.

Respectfully submitted,

<u>/s/ Thomas J. Sugrue</u>
Vice President Government Affairs
T-Mobile USA, Inc.
401 9th Street, NW
Suite 550
Washington, DC 20004

cc:	James A. Barnett, Jr	Bruce Liang Gottlieb	James Schlichting
	Stuart Benjamin	Evan R. Kwerel	Walter Strack
	Jeff Cohen	John Leibovitz	Joel Taubenblatt
	Paul de Sa	Jennifer Manner	Peter Trachtenberg
	Monica Desai	Charles Mathis	Margaret Wiener
	David Furth	Ruth Milkman	Jeff Goldthorp
	Angela Giancarlo	Paul Murray	Julius Knapp
	John Giusti	Louis Peraertz	Tom Peters
	Nese Guendelsberger	Susan Singer	Nicole McGinnis

Roberson and Associates, LLC
Technology and Management Consultants

Whitepaper: Technical Analysis of the Proposed 700 MHz D-Block Action

August 23, 2010

Prepared for T-Mobile by:

Roberson and Associates, LLC

Contributors:
N. Buris
K.S. Natarajan
E. Porrett
D. Roberson
K. Zdunek

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Summary

This whitepaper provides additional technical analyses of the effects of auctioning the 700 MHz D-Block for shared commercial/public safety use, as recommended in the National Broadband Plan and in the FCC's own analysis, with a specific focus of the effect of this action on public safety communications. The allocation of the Public Safety Broadband Spectrum block adjacent to the D-Block, combined with the convergence of commercial and public safety entities on a common standard (LTE), presents a unique opportunity to provide for public safety needs while also allowing for commercial benefit. It is our view that the critiques of this direction to date have sought to frame the discussion in a narrow context that omits critical information from their assessments. Addressing the proposed action from a broader, more technically inclusive perspective demonstrates that public safety needs can be satisfied and that the concerns that have been raised can be answered appropriately.

Our analysis shows the following:

1. Capacity for Public Safety

   The capacity and throughput provided by a 5+5 MHz LTE network in the 700 MHz public safety broadband spectrum is sufficient on a system and sector-cell basis to meet immediate Public Safety broadband (non-voice) spectrum needs for day-to-day and incident scene scenarios, as long as the network is designed as a high cell-density (low-site) network, and the 50MHz of 4.9 GHz public safety broadband spectrum is used in a coordinated manner. Specifically, high-quality video can be provided by the wide-area LTE network over a broad geographic area. Technology solutions exist to provide increased throughput at the cell-edge if necessary. Furthermore, additional concentrated capacity can be provided at incident scenes, if required, by vehicular mounted 700 MHz pico-cells, and on-line, vehicular-mounted, multi-band wireless routers operating at 4.9 GHz. This combination represents a practical and cost-effective solution to the challenge of providing public safety broadband communications over a wide-area, while also providing for high-capacity in a small geographic area when demanded by the incident.

   Further, consideration of the total amount of narrowband voice spectrum available to public safety, taking into account the significant increases in voice capacity that will be realized in the future due to narrowbanding in the VHF and UHF bands, and the reconfiguration of the 800 MHz band, prompt the discussion of a future repurposing of a portion of the 700 MHz public safety narrowband spectrum for broadband use. This would provide the additional bandwidth necessary to accommodate dispatch voice service in an integrated and interoperable fashion with broadband applications. Already requested by some public safety agencies, the combination of the 10 MHz of 700 MHz public safety broadband spectrum with a portion of the currently allocated 700 MHz narrowband spectrum would allow a seamlessly integrated voice, data, and video public safety broadband network to be deployed, and would increase the maximum per user throughput and overall capacity achievable within the dedicated public safety network.

2. Use of D-Block Commercial Networks by Public Safety

   The LTE standard allows for the design of a commercial network in the 700 MHz D-Block that can effectively provide public safety users with additional broadband capacity during major emergencies and disaster situations. The LTE standard provides a sufficient number and range of types of priorities to allow provisioning of commercial D-Block networks so that public safety users can achieve any desired priority level, including the insertion of public safety packet streams onto otherwise fully loaded traffic channels. This is possible because of the packet nature of communications on LTE compared to the circuit-based 2G and 3G networks. Further, mechanisms exist within the LTE access channel protocols to selectively inhibit service requests from classes of users during periods of heavy use, so that the access channel can be prioritized to ensure access for high priority public safety users. Flexible, cost effective, and dynamic approaches for apportioning traffic between the 700 MHz dedicated public safety broadband network and commercial D-block networks are possible within LTE.

3. Interference

Any potential for adjacent band interference between the commercial D-Block and the Public Safety Broadband Block can be readily avoided if both systems are based on the LTE standard and they use similar system design guidelines with comparable cell sizes. The LTE standard provides for systems to operate in adjacent spectrum, and any more stringent coverage standards for public safety networks can be addressed as a part of the initial system design. A coordinated system design will not only prevent interference, it will also facilitate spectrum sharing as urgent needs dictate that the commercial spectrum be re-prioritized to support public safety communications. The ideal situation as described in the NBP and FCC Whitepaper is for the dedicated public safety network base sites to share infrastructure and be co-located whenever possible with the commercial D-Block sites. Co-location of public safety and commercial base site equipment is not uncommon today and should not present an impediment to deployment. Additionally, analysis of the potential interference generated by user device transceivers with integral GPS receivers in the same device shows that any potentially harmful interference can be avoided with a number of well-known methods, including transmit filtering.

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1.0 Introduction

The National Broadband Plan (NBP), released on March 16, 2010 by FCC Chairman Julius Genachowski, recommends that the 10 MHz of 700 MHz radio frequency spectrum designated by Congress for public safety use be utilized by public safety agencies to construct a dedicated national broadband network.[1] The NBP further recommends that incentive-based partnerships with commercial entities such as 700 MHz service providers, with the support of public funding, be a vehicle for constructing the network. Desirable cost efficiencies are achieved by leveraging commercial infrastructure and technologies already in place or being developed for the 700 MHz band, such as the 3GPP's Long Term Evolution (LTE) standard suite.

The NBP recognizes that while a dedicated 10 MHz network can provide a core for public safety broadband communications, additional public safety capacity is necessary in emergencies. Thus, the NBP calls for the FCC to formulate rules ensuring that public safety users can roam and be allowed priority access on commercial 700 MHz broadband networks. Since the 700 MHz D-Block shares the same 3GPP LTE band class as the public safety broadband spectrum, the D-Block is a main candidate for achieving this capability. Deploying the D-Block for commercial use also creates economies of scale that public safety can leverage in its own dedicated spectrum.

Since the NBP's release, numerous businesses, state and local governments, and non-profit entities have commented on the feasibility and effectiveness of the NBP's recommendations in satisfying public safety needs for broadband communications. Even more entities have commented on the FCC Whitepaper[2] that analyzes the capacity and performance of the recommended broadband network. The explicit conclusion of the Whitepaper is that the NBP plan, when fully implemented, would meet public safety needs for a national wireless broadband infrastructure.

On the one hand, there are supporters of the NBP who agree with its recommendations and with the FCC Whitepaper. On the other hand, critics have pointed out alleged technical flaws in the NBP and with the FCC analysis, and propose that the 700 MHz D-Block be combined with the existing 10 MHz public safety broadband allocation, dedicated to public safety, and used for the construction of a 20 MHz national broadband network.[3]

The purpose of this whitepaper is to bring additional technical information forward in order to better assess the effectiveness and feasibility of deploying a public safety broadband network in the 10 MHz of dedicated spectrum at 700 MHz, and utilizing commercial D-Block networks by public safety during emergency situations. Our view is that by bringing this information to light, better and more informed decision making should result. The analyses presented here show that the NBP is both very feasible and effective in meeting public safety needs when considered in the context of the totality of spectrum that is available to public safety, and the additional capacity afforded by the D-Block during times of emergencies.

[1] *See Connecting America: The National Broadband Plan*, The Federal Communications Commission, Chapter 16 (Mar. 2010), *available at* http://www.broadband.gov/download-plan/ (*National Broadband Plan*).

[2] *See The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance, and Cost*, The Federal Communications Commission (Jun. 2010), *available at* http://fcc.gov/pshs/docs/releases/DOC-298799A1.pdf (*FCC Whitepaper*).

[3] *See* Letter to Ms. Marlene H. Dortch, Secretary, Federal Communications Commission, from Mr. Steve B. Sharkey, Senior Director, Motorola Inc., PS Docket No. 06-150, Apr. 12, 2010, (*Motorola Presentation*); *see also* Letter to Ms. Marlene H. Dortch from Mr. Andrew M. Seybold, PS Docket No. 06-229, Jun. 23, 2010 ("Comments on: FCC White Paper, The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance, and Cost") (*Seybold Comments*).

2. Public Safety Capacity and Throughput

2.1 Summary of the FCC Whitepaper

The FCC Whitepaper concludes that the currently allocated 10 MHz of dedicated 700 MHz public safety broadband spectrum meets immediate day-to-day, emergency, and incident-scene needs of public safety, specifically with regard to real-time video communications. This conclusion is based on an analysis of the total capacity available across a public safety network consisting of small (geographic area) cells. Appropriate emphasis is placed on the fact that in a multi-cell wireless network, total capacity is a direct function not only of the total bandwidth available, but also of the number of cell-sites, the number of radio-coverage sectors per cell-site, and importantly, the efficiency of the modulation technique chosen, as measured in bits-per-second per Hz of RF bandwidth.

Significantly, the FCC capacity and throughput analysis contained in the *FCC Whitepaper* is the only recent, comprehensive and quantitative analysis of public safety RF bandwidth needs based on broadband capacity and throughput requirements. The FCC analysis properly takes into account the aggregate bandwidth demand of a population of public safety users and devices, based on the throughput (bit rate) requirements of each application, and the utilization factor of each user. Previous analyses fail to take this comprehensive and highly appropriate approach.[4] For example, the needs analysis provided by the Public Technology Institute gives descriptions of public safety data application categories, but presents no quantitative information on utilization levels or capacity demands.[5] In contrast, the *FCC Whitepaper* uses specific public safety scenarios derived from actual incidents to quantitatively evaluate spectrum demand; consideration is given to the geographical extent of the incident and the number of RF sectors (and resulting RF carriers) that would be expected to serve the incident.

The *FCC Whitepaper* also acknowledges that the demands on the dedicated public safety network during extreme disaster situations will likely cause its base capacity to be exceeded. Therefore, mechanisms should be put into place to provide for public safety users to "roam" onto commercial networks during these situations, and be granted priority access so that the most effective use of the bandwidth for the benefit of the public during these times of emergency is achieved. The mechanisms for this capability are described in Section 3.

Several comments filed with the FCC in response to the NBP and the *FCC Whitepaper* have criticized the conclusion that a dedicated 10 MHz LTE public safety broadband network can meet basic broadband and video communications needs of public safety. The comments have raised the following issues:

- Insufficient capacity and throughput for high-quality video.[6]
- No mechanism for moving public safety user equipment to operate on commercial networks during emergency situations.[7]

These criticisms are addressed in the following sections.

[4] *See* Letter to Ms. Marlene H. Dortch from the City of New York Department of Information and Technology, WT Docket No. 06-150, filed Feb. 23, 2010 ("700 MHz Broadband Public Safety Applications and Spectrum Requirements") (*NYC Requirements*) *available at* http://www.iwceexpo.com/iwce2010/CUSTOM/700MHz%20Whitepaper%20on%20Spectrum%20Feb%202010%20FINAL.pdf; *see also Seybold Comments*.

[5] *See* Public Technology Institute, "700 MHz D Block: Public Safety Applications Needs Assessment", *available at* http://www.pti.org/docs-safety/pti-Public%20Safety%20White%20Paper_2010.pdf.

[6] *See Motorola Presentation*, *Seybold Comments*.

[7] *See Motorola Presentation* at p. 32.

2.2 Meeting the Broadband and Real-Time Video Capacity Needs of Public Safety

Based on the 3GPP LTE standard, subsequent validation testing, and previous comments filed, it is known that per-sector throughput rates of 7.5 to 10 Mbps downlink and 3.5 to 5 Mbps uplink are achievable for the 10 MHz (5+5 MHz) public safety broadband network.[8] This throughput capacity is shared by the public safety users and their applications within a RF coverage sector. The discussion here will focus on the demand and capacity for real-time, streaming video communications, since this application is the most demanding on wireless network capability.

Critical items for discussion are: a) the quality level of real-time video transmission required for various public safety scenarios, and the corresponding video bit rate per user or per device; b) the geographic extent of the deployment of public safety users and devices responding to the incident; c) the number of users and devices operating at the different bit rates, and the utilization factor of those users.

2.2.1 Video Bit Rate Required for Public Safety

Comments filed with the FCC indicate a need for real-time video communications ranging from 256 kbps to 1.2 Mbps,[9] up to as high as 3 Mbps.[10] The FCC Whitepaper assumes a maximum rate of 512 kbps in its capacity calculations. In the analysis here we assume a more stringent requirement of 1.2 Mbps rate (high quality video), consistent with the analysis in the *Motorola Presentation.*

2.2.2 Geographic Extent of the Incident Scene: Number of Video Streams Able to be Provided

The FCC Whitepaper analyzes four incident scenarios. These are: Dirty Bomb in New York City,[11] New York City Network Growth need for Major Urban Environment,[12] Collapse of the Minneapolis Bridge,[13] and Hurricane Ike.[14] The latter two scenarios are based on real incidents. The assumptions on the geographic extent of each scenario are such that multiple cells and sectors provide coverage for the incident scenes. Since overall capacity in a geographic area is multiplied by the number of sectors (RF carriers) that serve the incident scene,[15] the FCC analysis concludes that with a maximum 512 kbps video rate, the video and data communications needs of each incident are met. (Appropriate assumptions on the number of users and utilization level of the users and devices are used in the calculations). The assumption that an incident scene is served by multiple cell

[8] This represents a consensus of the *FCC Whitepaper*, *Motorola Presentation*, *Seybold Comments* and the remarks of Ericsson. *See* Transcript of Record at 39, *700 MHz Nationwide Interoperable Public Safety Wireless Broadband Network Workshop* (Mar. 17, 2010) (see testimony of Mr. Patrick Ringqvist, Vice President, Wireless Network Solutions, Ericsson, Inc.).

[9] *See* National Public Safety Telecommunications Council, Public Safety 700 MHz Broadband Statement of Requirements (2007) at p. 39.

[10] *Motorola Presentation* at p. 9.

[11] *See FCC Whitepaper* at p. 19; *see also* Letter to Ms. Marlene H. Dortch from the City of New York Department of Information and Technology, PS Docket No. 06-229, filed Nov. 17, 2009 (*New York City Filing*).

[12] *See FCC Whitepaper* at p. 22 *and New York City Filing* at p. 10.

[13] *See FCC Whitepaper* at p. 25; *see also Emergency Communications during the Minneapolis Bridge Disaster: A Technical Case Study of the Federal Communications Commission's Public Safety and Homeland Security Bureau's Communications Systems Analysis Division,* Federal Communications Commission at 16-17 (Nov. 2008), *available at* http://www.fcc.gov/pshs/docs/clearinghouse/references/minneapolis-bridge-report.pdf.

[14] *See FCC Whitepaper* at p. 32, and Emergency Communications during Hurricane Ike, A Technical Case Study by the Federal Communications Commission's Public Safety and Homeland Security Bureau's Communications Systems Analysis Division, *available at* http://www.fcc.gov/pshs/docs/clearinghouse/case-studies/Hurricane-Ike-Harris%20County-120109.pdf.

[15] *See FCC Whitepaper*.

sites or sectors within a cell site has come under criticism, since it is observed that many incidents take place within a relatively small area.[16] Rather than debate the assumptions on the geographic area of an incident scene, the table below shows how the aggregate number of simultaneous uplink and downlink streams for a public safety incident varies as the cell size (radius of coverage) and geographic (areal) extent of the incident varies. A uniform distribution of public safety users and devices is assumed in the incident scene area for this analysis. A further assumption is that there are 3 RF sectors (LTE carriers) per cell site. Average per-sector throughput rates are assumed. (A discussion of cell-edge issues is contained in Section 2.2.4.)

		Potential Number of RF Sectors Serving an Incident				Potential Number of 1.2 Mbps Downlink Streams				Potential Number of 1.2 Mbps Uplink Streams			
		Incident Area (sq. miles)				Incident Area (sq. miles)				Incident Area (sq. miles)			
Cell Size (radius, meters)	RF Sector Area (sq. miles)	0.5	1	2	4	0.5	1	2	4	0.5	1	2	4
500	0.10	4	9	19	39	25	56	118	243	11	26	55	113
750	0.23	2	4	8	17	12	25	50	106	5	11	23	49
1000	0.41	1	2	4	9	6	12	25	56	2	5	11	26
1500	0.92	1	1	2	4	6	6	12	25	2	2	5	11

Table: Variation in Number of Downlink and Uplink Video Streams as a Function of Incident Scene Area and Cell Size (3 Sectors per Cell)

Unsurprisingly, incident scenes that occur in areas where there are small cell sizes (typically, urban areas), are served by a large number of sectors, and can be provided with a large number of high-quality uplink or downlink streams. For incidents that occur in a very small area where there are larger cells (typically, sub-urban or rural areas), a relatively smaller number of video streams are able to be provided. The conclusion is that even for incidents served by a single RF sector, useful numbers of high-quality downlink and uplink video streams are able to be provided.

Technology developments to improve LTE throughput continue at a rapid pace, and recent LTE trials indicate that the average throughputs of a 10 MHz LTE sector may be as high as 10 Mbps downlink, increasing the video capacity correspondingly.[17] Use of lower video rates will result in the ability to support a larger number of streams. For example, use of 512 bps video would double the number of streams able to be provided.

The table further shows that the number of high-quality video streams *scales*, as would be desired, with the geographic extent of the incident. For situations in small geographic areas that require more video capacity, additional mechanisms are available, as described in the next section.

2.2.3 Role of Pico-Cells and 4.9 GHz

The challenge of providing greater capacity levels for high-quality video for compact incident scenes can be met in two ways. As described in the *FCC Whitepaper*, Cell Sites on Wheels or “Mobile Pico-Cells” can be rapidly deployed to augment capacity when it is known that an incident has occurred in an area where there are large cell sites. The 700 MHz mobile pico-cell solution (with wireless backhaul) is particularly suited to bringing additional sectors (and additional capacity) to bear on an in-building incident where 700 MHz propagation characteristics provide in-building RF penetration. It is recognized that deploying mobile pico-cells

[16] *Seybold Comments*, and implied in analysis in *Motorola Presentation*.

[17] *See* LTE SAE Trial Initiative (Feb. 2009) *available at* http://www.lstiforum.com/file/news/Latest_LSTI_Results_Feb09_v1.pdf (*LTE SAE Trial*).

could take additional time and may not be suited to all incidents. A highly effective and complementary approach is to use small form-factor, vehicle mounted, 4.9 GHz mobile wireless routers (mobile hot-spots) that can be very rapidly deployed to provide high-quality video communications capacity when needed in small-geographic areas. It is not impractical to envision that a high proportion of public safety vehicles would have multiband wireless router capabilities, providing a near instantaneous on scene capacity increase. The propagation characteristics of 4.9 GHz are ideally suited to providing high capacity in geographically compact areas, complementing the mobile wide-area communications capability of the 700 MHz broadband network.

Regarding the feasibility of 4.9 GHz video communications, suppliers have already begun to develop and market multi-band wireless routers, anticipating the coordinated use of the 700 MHz and 4.9 GHz public safety bands as well as the unlicensed bands used for Wireless LAN.[18] Systems are being planned and deployed that use 4.9 GHz for mobile communications, not just point-to-point.[19] Vehicular mounted wireless routers also allow for higher efficiency (gain and directive) antennas to be used for backhaul. The use of 4.9 GHz to provide high-quality fixed video surveillance over a large metropolitan area (City of Chicago for example) is well known.[20]

It is therefore concluded that, contrary to the views of a few critics,[21] the 50 MHz of spectrum at 4.9 GHz is not only useful, but also a critical asset for public safety incident scene communications. This utility can be further enhanced when the 4.9 GHz system is used in combination with the capabilities of the 10 MHz wide-area 700 MHz public safety network. 4.9 GHz networks can be flexibly deployed with channel sizes ranging from 1 MHz to 20 MHz,[22] to allow for a large number of high-quality video channels to be deployed in a small incident scene area. These systems can be configured to have a limited range, providing for high degrees of reuse, or they can be configured to provide point-to-point communications for longer range backhaul applications if needed.[23]

2.2.4 Throughput for Video at the Cell Edge

A known characteristic of high spectral efficiency modulation techniques such as used in LTE is a reduction in throughput as a function of increased distance of the user device from the base site. Representative sets of performance results at different mobility speeds are available in the literature.[24] The shape of a typical Downlink (DL) throughput curve is shown below. The variation of throughput as a function of SINR (signal to interference plus noise ratio) has been experimentally measured in a large commercial LTE network

[18] *See Overview—Cisco Support for 4.9 GHz Public Safety Broadband Spectrum in the United States*, Cisco Systems Inc. (2005), *available at* http://www.cisco.com/en/US/prod/collateral/routers/ps272/prod_brochure0900aecd802d816e.pdf.

[19] *See* Geoff Kohl, *Going Mobile with Video Surveillance on Chicago's Bus System*," SECURITYINFOWATCH.COM, Feb. 2, 2009, *available at* http://www.securityinfowatch.com/root+level/1284404.

[20] *See* T. Romanelli, *Chicago's Surveillance Strategy*, LAW AND ORDER, Oct. 2009, *available at* http://www.hendonpub.com/resources/articlearchive/details.aspx?ID=207538.

[21] See *Seybold Comments* and *NYC Requirements*.

[22] *See* Rinehart and D. Eierman, Motorola Inc., *4.9 GHz Public Safety Broadband Spectrum: Overview of Technical Rules and Licensing Instructions*, *available at* http://www.npstc.org/meetings/Rinehart%204.9%20GHz%20Regulatory%20Overview%201-20-05.pdf.

[23] *See* S. Churchill, *4.9 GHz Band Growing*, DAILYWIRELESS.ORG, *available at* http://www.dailywireless.org/2008/07/31/49-ghz-band-growing/;

[24] *See LTE SAE Trial*; *see also* Julius Robson, *LTE Part II: 3GPP Release 8 – The LTE/SAE Trial Initiative: Taking LTE/SAE from Specification to Rollout*, IEEE COMMUNICATIONS MAGAZINE, Apr. 2009, pp. 82-88.

implemented in Stockholm.[25] This variation in throughput as a function of distance from the base site must be considered when evaluating public safety video capacity.[26]

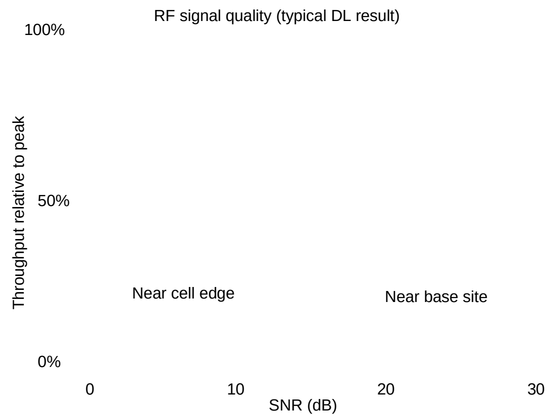

Figure: Conceptual Relative Downlink (DL) Throughput as a Function of Distance from Base Site

Fortunately, several solutions already exist to improve cell-edge throughput, as well as overall capacity, coverage, and range. First, higher gain user device external antennas, more practical for public safety equipment than for commercial equipment which use internal antennas, can improve the SNR (signal to noise ratio) by 3 to 5 dB[27] with a corresponding increase in data throughput at the cell edge. Mobile pico-cells can be used to improve overall capacity as well as throughput. Mobile relays and distributed antenna systems, while not able to improve capacity, can also significantly extend the coverage range of a cell site, or improve the link margin and increase the data rate (throughput) to user devices. Several multiple antenna transmission modes have been defined for LTE to optimize different downlink performance measures under varying radio conditions.[28] The diversity schemes as well beam steering methods are geared to improve signal robustness at the user device, effectively improving cell edge performance. The high-order MIMO methods use spatial multiplexing to improve system capacity under good radio signal conditions. In practice, adaptive antenna schemes are implemented to optimize performance under all signal conditions.

Beam steering methods focus the signal power in a particular direction and have the effect of increasing signal strength and data rate. The effectiveness of beam steering increases with the number of transmitting antennas at the base site. This in turn enables the creation of a narrower, higher-gain beam. Variations are permitted that

[25] *See* Sten Andersson, *RTG-OPASTCO 700 MHz Workshop – Ericsson LTE 700 MHz Overview*, July 25, 2010, presentation slide 7, *available at*http://www.opastco.org/doclibrary/2064/ericsson_andersson.pdf *(Stockholm-LTE-Network).*

[26] *See Realistic LTE Performance, from Peak Rate to Subscriber Experience*, Motorola Inc. *available at* http://ap1.motorola.com/LTE_assets2/pdf/Realistic_LTE_Experience_WhitePaper.pdf *(Motorola LTE Performance).*

[27] Internal antennas, commonly employed in cell phones held by hand next to the ear, have a nominal radiation efficiency of 8-12%, while external antennas commonly employed in public safety handheld devices have a nominal radiation efficiency when held near the mouth of 30-40%. Using nominal radiation efficiencies of 10% for a cellphone, and 35% for a public safety radio, the radiation efficiency advantage for a public safety device is therefore 10 x log (35/10) = 5.4 dB. This performance can be considered representative of the differences between commercial and public safety devices.

[28] These include: Receive diversity (SIMO), Open-loop transmit diversity (MISO), Open-loop spatial multiplexing – MIMO without precoding (Single-User MIMO), Closed-loop spatial multiplexing – MIMO with precoding, Multi-User MIMO and MISO beamsteering methods. (Note: SIMO – Single Input Multiple Output, MISO – Multiple Input Single Output, MIMO – Multiple Input Multiple Output).

allow the formation of a dedicated beam towards the User Equipment (UE), including a UE-specific beamformed reference signal. Early implementations of adaptive beam-steering antennas by several vendors have demonstrated improvements in overall coverage, range, and the throughput of user devices operating at the cell edge.[29]

The LTE standard has also provided for multiple antenna techniques for the uplink that improve performance and/or robustness to signal quality impairments. These include: Receive diversity at the base site, Single-User Multiple Input Multiple Output (MIMO) systems for single UE and Multi-User MIMO for multiple UE. In addition to the various options in the LTE Release 8 specs,[30] a variety of performance improvement features will be included in the imminent next release of the LTE-Advanced standard (Release 10 and beyond). These include: a) Higher order MIMO and beam steering, b) Co-operative MIMO, c) In-channel relay and d) Cell-edge interference coordination and cancellation techniques. As described immediately above, MIMO techniques in general improve capacity and throughput in moderate and strong signal conditions within a cell, while conventional diversity and beam steering techniques improve performance at the cell edge, as well. A detailed explanation of these features is outside the scope of this paper but readily available in the standards documents and elsewhere in the literature. Diligent exploitation by interested stakeholders (vendors and public safety/commercial operators) of the different capabilities already in the current LTE standard (Release 8) and imminent LTE-Advanced (Release 10 and beyond) are adequate to handle foreseeable data rate requirements (average as well as cell edge) under a variety of environmental scenarios and radio conditions.

Early measurements of LTE field trials implementations have been reported in the open literature.[31] The figure on slide 12 of *LTE Field Trial* depicts LTE downlink spectral efficiency measured independently by 6 leading operators in field trials incorporating multiple LTE base sites. The normalized average cell capacity for a 20 MHz system is 40 Mbps. It is reasonable to extrapolate that a 5 MHz system will have a normalized average cell capacity of 10 Mbps. This is significantly higher than what the FCC assumed (7.5 Mbps) or the Motorola predictions on expected performance (8.7 Mbps in *Motorola LTE Performance)*. Further optimization of system performance has the potential to increase cell capacity even further.

2.3 Dynamically Moving Public Safety Devices from Public Safety Networks to Commercial Networks

The FCC Whitepaper and NBP plan recommend that public safety devices utilize the commercial D-Block network in extreme emergency situations. A criticism of this approach is that there is no mechanism for a public safety device or user operating on the dedicated public safety network to "know" when it should switch to the commercial network.[32] It turns out that the need to be able to dynamically and securely "reprogram" public safety user equipment has been understood for many years, and the basic outline of mechanisms to accomplish

[29]*See*: (1) Multi-Antenna Signal Processing: Drivers of Adoption in 3.5G, LTE, and WiMAX, ArrayComm Inc. (Oct. 2006) *available at* http://www.arraycomm.com/docs/ArrayComm_MAS_Adoption_Drivers.pdf; (2) Mondal, et al., Method and Apparatus for Performing Spatial-Division Multiple Access, U.S. Pat. Pub. 2007/0183362 (Aug. 9, 2007); (3) Whinnett et al., Frequency Transformation Based Transmit Beamforming in a Communications System, U.S. Pat. Pub. 2010/0008268 (Jan. 14, 2010); (4) F. Wang et al, Mobile assisted downlink beamforming with antenna feedback, U.S. Pat. No. 7,747,225 (Jun. 29, 2010); (5) F. Vook et al., Method and apparatus for multi-antenna transmission, U.S. Pat. Pub. 2004/0178954; (6) J. Choi and R. W. Heath, System and method for interpolation based transmit beamforming for MIMO-OFDM with partial feedback, U.S. Pat. No. 7,676,007 (Mar. 9, 2010).

[30] *See* 3GPP Service 36 series (LTE) specifications, 3rd Generation Partnership Project, *available at* http://www.3gpp.org/ftp/Specs/archive/36_series.

[31] *See Update of Latest Results*, LSTI Presentation at LTE World Summit, Amsterdam (May 2010),

available at http://www.gsacom.com/downloads/pdf/LSTI%20presentation_Amsterdam_May2010_final.php4 *(LTE Field Trial)*.

[32] *See Motorola Presentation* and *Seybold Comments*.

this reprogramming have been known for some time as well.[33] It is envisioned that specific mechanisms to inform public safety users that they should switch to a commercial 700 MHz network, or that mechanisms to cause user devices to automatically be reconfigured to switch, will be provided if that is determined to be useful. Provision for the implementation of such communication "storm plans" is well known in the public safety communications area. (Storm plans call for public safety user groups to operate on particular channels or talk-groups in pre-defined emergency scenarios.)

2.4 A Long-Term Roadmap for 700 MHz Public Safety Spectrum.

In 1997, 12 MHz of the 24 MHz in the 700 MHz band to be re-allocated from broadcast television to public safety use was designated for narrowband, traditional (conventional and trunking) voice operation. Since that time, wireless technology and applications have made dramatic advances. The ability of wireless equipment to efficiently use radio frequency bandwidth, as measured by a spectral efficiency metric such as (user bit rate) per (Hz of RF bandwidth), has increased dramatically. Video and audio codec technology and algorithms have advanced as well, with corresponding dramatic decreases in the bit rate required for those services. The use of the Internet Protocol (IP)-based packet communications networking technology has advanced so that voice, data, and multimedia (video) content can be transported in a unified manner on wired as well as wireless networks such as those based on the 3GPP LTE standard.

2.4.1 Assessment of Public Safety Narrowband Voice Spectrum and Capacity

The following table summarizes the amount of narrowband spectrum available to public safety, as reported in several sources,[34] in three different deployment epochs. In Epoch 1, "Current Narrowband Spectrum," the column labeled "Current Spectrum" lists the total bandwidth available to public safety, excluding the 700 MHz narrowband allocation. The column labeled "Current Voice Channels/Area" lists the resulting number of voice channels, assuming a 2 x 25 kHz duplex channel pair per voice channel. For a conservative estimate, only UHF (450-470 MHz) and 800 MHz spectrum is considered. Although there is considerable spectrum at VHF, systems in this band may be difficult to upgrade to more efficient technologies or configurations. The corresponding number of public safety users in the "Users/Area" column lists the number of active public safety users that can be supported by these voice channels, given the FCC loading criteria of 70 users per voice channel.[35] Also, this assessment does not include the 470-512 MHz band spectrum used in 11 US cities.

In Epoch 2, "Available Narrowband Spectrum," the columns list the Available Bandwidth, Available Voice Channels, and corresponding users available to be supported for public safety as in Epoch 1, but also include the effects of narrowbanding to an equivalent 6.25 kHz/voice channel path, as described in the FCC narrowbanding rules and conforming APCO Project 25 air interface standard.[36] Also included in these columns is the effect of the additional channels and voice capacity made possible by the 800 MHz band reconfiguration.[37] It can be seen that compared to the situation prior to narrowbanding and the 800 MHz reconfiguration, (and again excluding

[33] *See* Comroe, et al., Method for Dynamically Regrouping Subscribers on a Communication System, U.S. Pat. No. 5,014,345 (May 17, 1991).

[34] *See FCC Whitepaper; see also* Letter to Hon. Julius Genachowski, Chairman, Federal Communications Commission, from Chief Harlin R. McEwen, International Association of Chiefs of Police, PS Docket No. 06-229, filed Oct. 12, 2009 (stating "Public Safety Radio Communications-Wireless Broadband is not an Alternative to LMR Mission Critical Voice Systems") (*McEwen Ex Parte*).

[35] *See* 47 C.F.R. § 90.633.

[36] *See Promotion of Spectrum Efficient Technologies on Certain Part 90 Frequencies,* Third Memorandum Opinion and Order, Third Further Notice of Proposed Rulemaking and Order, 19 FCC Rcd. 25045 (rel. Dec. 23, 2004). APCO Project 25 standard documents can be found at http://www.tiaonline.org/standards/committees/committee.cfm?comm=tr-8; *See also* J.S. Powell, *Narrowbanding: It's Now the Law as FCC Issues Final Rules*, POLICE CHIEF MAGAZINE, *available at* http://policechiefmagazine.org/magazine/index.cfm?fuseaction=display_arch&article_id=572&issue_id=42005.

[37] *See McEwen Ex Parte*.

VHF), the number of available voice channels, and users able to be supported for public safety, more than doubles (from 264 to 576 voice channels, and from 18,480 to 40,320 active users). Narrowbanding and the 800 MHz reconfiguration therefore provide a significant increase in the narrowband voice-channel capacity available to public safety. Consideration of this additional narrowband voice capacity for direct unit-to-unit public safety communications for day-to-day incident scene needs, as well as for larger disasters and emergency situations, has not been taken into account by the critics of the *FCC Whitepaper* analysis of public safety capacity.[38]

Finally, the columns in Epoch 3, "Available Narrowband Spectrum with 700 MHz" include the effects of narrowbanding in UHF, reconfiguration in 800 MHz, *plus* the voice channels available in the 12 MHz of spectrum in the 700 MHz band allocated to public safety narrowband. Using the assumption of 2 x 25 kHz duplex channels at 700 MHz, 240 additional voice channels are added, corresponding to 16,800 users, for a grand total of 816 narrowband public safety voice channels, accommodating approximately 57,120 active public safety users in a geographic area. Again this excludes VHF spectrum, and does not take into account the additional user capacity available if multi-channel trunked systems are employed. 700 MHz therefore adds another 40% to the number of voice channels and narrowband voice user capacity available to public safety.

	Epoch 1 Current Narrowband Spectrum (25kHz voice bandwidth)			Epoch 2 Available Narrowband Spectrum (6.25 kHz voice bandwidth below 700 MHz) (without 700 MHz spectrum)			Epoch 3 Available Narrowband Spectrum (6.25 kHz voice bandwidth below 700 MHz) (with 700 MHz spectrum)		
	Current Spectrum (MHz)	Current Voice Channels /Area	Approx Users/ Service Area	Available Spectrum (MHz)	Available Voice Channels/Area	Approx Users/ Service Area	Available Spectrum (MHz)	Available Voice Channels/Area	Approx Users/ Service Area
Narrowband Spectrum									
25-50	6.3			6.3			6.3		
138-144/148-174	3.6			3.6			3.6		
220-222	0.1			0.1			0.1		
450-470	3.7	74	5,180	3.7	296	20,720	3.7	296	20,720
806-821/851-866	3.5	70	4,900	3.5	70	4,900	3.5	70	4,900
821-824/866-869	6.0	120	8,400	6.0	120	8,400	6.0	120	8,400
806-824/851-869 (reconfiguration)				4.5	90	6,300	4.5	90	6,300
Total Narrowband w/o 700 MHz	23.2	264	**18,480**	27.7	**576**	**40,320**	**27.7**	**576**	**40,320**
					700 MHz Narrowband		**12**	**240**	**16,800**
					Total Narrowband w. 700 MHz		**39.7**	**816**	**57,120**

Table: Narrowband Capacity Available to Public Safety, with and without 700 MHz

2.4.2 Potential Long-Term Future Roadmap for the 700 MHz Band

The packet-based air interface and architecture of LTE, and the use of Voice over Internet Protocol (VoIP), provide the opportunity for the design and deployment of a truly integrated and interoperable voice, data, and broadband (video) capable public safety network. The desirability of such an integrated network has been pointed out by major public safety agencies.[39] Significantly, public safety agencies, seeing the efficiency and interoperability benefits of integrated voice, data, and video wireless networks, are already exploring and petitioning to develop such integrated networks in the 700 MHz band.[40]

[38] *See Seybold Comments*.

[39] *See New York City Requirements*.

[40] *See* (1) City of New York Petition for Waiver, PS Docket No. 06-229, filed Jun. 8, 2009; (2) City of Boston Amended Request for Waiver, PS Docket No. 06-229, filed May 28, 2009; (3) State of New Jersey Petition for Waiver, PS Docket No. 06-229, filed Apr. 3, 2009; *and* (4) State of North Dakota Petition for Waiver, PS Docket No. 06-229, filed Jul. 17, 2009.

Networks of this type, needing to accommodate voice communication in addition to broadband and data communications services, would require additional capacity and bandwidth. Public safety bandwidth needs for this type of integrated service, however, should be evaluated in the context of the total spectrum available to public safety, not just the 700 MHz band. As described above, narrowbanding and the 800 MHz rebanding will triple (from 264 to 816) the number of duplex voice channels potentially available to public safety in just the UHF and 800 MHz bands. In light of these increases in traditional narrowband voice capacity, and the increased demand and capability for IP (internet protocol) based communication services, the allocation of 12 MHz of narrowband spectrum at 700 MHz, made in 1997 and based on 14 year old technology projections, should be re-evaluated.[41]

In the future, repurposing of 10 MHz of the existing public safety narrowband spectrum for *broadband* use would allow a 20 MHz broadband LTE public safety network to be deployed, providing the increased capacity necessary to add and integrate voice communications on the national broadband network. This repurposing of narrowband spectrum could occur over a transitional period based on geography, spectrum needs, and other factors. The figure below illustrates one approach for long-term repurposing of the 700 MHz spectrum. However, other approaches also exist to transition the spectrum from narrowband to broadband use.

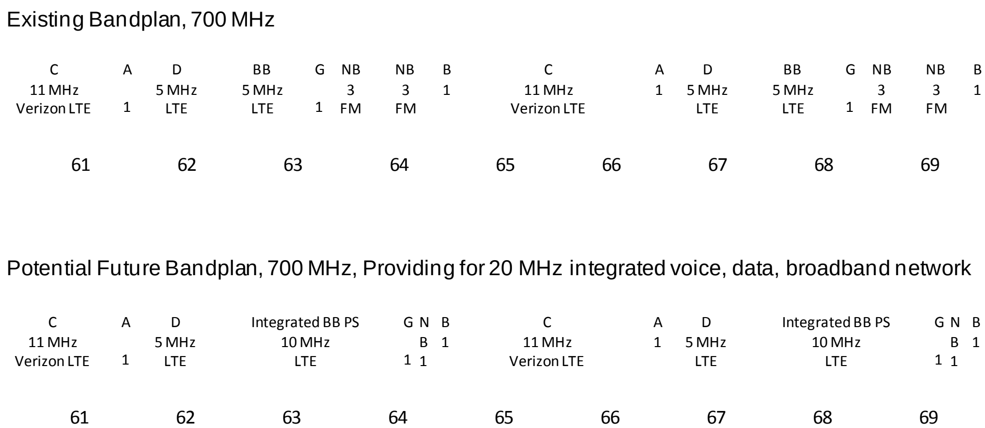

Figure: Repurposing of 700 MHz Public Safety Narrowband Spectrum for an Integrated Voice and Data Network.

In this scheme, 2 MHz of the narrowband public safety spectrum in the 700 MHz band would remain, providing for 40, 25 kHz duplex channel (or 80, 12.5 kHz channels) for interoperability. The effect on overall narrowband public safety voice capacity is shown in the Table below. There would be 616 total duplex narrowband voice channels available for public safety in the UHF, 800 MHz, and 700 MHz bands, down from the 816 available with 12 MHz of narrowband 700 MHz spectrum. This still represents an increase of well over *double* the number of narrowband channels available in UHF and 800 MHz today (without narrowbanding), and provides for substantially more voice capacity via VoIP on the multi-cell LTE network due to frequency reuse. Since there are still 40 channels of narrowband conventional voice channels available immediately adjacent to the broadband channels, public safety user equipment could be designed to operate on the 20 MHz integrated voice, data, and video network when in range of the LTE network, but be able to switch when necessary into the "talkaround" mode for direct unit-to-unit communications when utilizing the LTE network is unfeasible.[42] A commercial cellular carrier provides for this type of operation today.[43] The flexibility for providing for direct

[41] 1997 FCC ruling designating 12 MHz for public safety narrowband. [can you give the specific order citation?]

[42] "Talkaround" is land mobile radio terminology for direct transmissions between user handheld devices, bypassing or "talking around" the repeater that would normally be used as a relay for unit-to-unit communications.

[43] *See* "Direct Talk[SM], the Off-Network Walkie-Talkie," Sprint-Nextel Inc., *available at* http://www.nextel.com/assets/pdfs/en/support/guides/services/walkie_talkie/direct_talk_qsg.pdf.

unit-to-unit communications in the same device that also operates on the broadband network answers the concern for the continuing need for traditional voice services.[44]

	Potential Long-Term Future Available Narrowband Spectrum (6.25kHz voice bandwidth below 700 MHz) (with 700 MHz spectrum)		
	Available Spectrum	Available Voice Channel Equivalent	Approx Users/ Service Area
Narrowband Spectrum			
25-50	6.3		
138-144/148-174	3.6		
220-222	0.1		
450-470	3.7	296	20,720
806-821/851-866	3.5	70	4,900
821-824/866-869	6	120	8,400
806-824/851-869 (reconfiguration)	4.5	90	6,300
Total Narrowband w/o 700 MHz	27.7	**576**	**40,320**
700 MHz Narrowband	**2**	**40**	**2,800**
Total Narrowband w. Alt. 700 MHz	**29.7**	**616**	**43,120**

Table: Narrowband Capacity Available to Public Safety with Repurposing of 10 MHz Narrowband Spectrum

3. Use of D-Block Commercial Networks by Public Safety

The NBP recognizes that while the dedicated 10 MHz broadband network it proposes can provide public safety a core broadband communications facility, the need for additional public safety capacity during emergencies and large-scale disaster scenarios is inevitable. Thus, the NBP calls for the FCC to formulate rules ensuring that public safety users can roam with priority access on commercial 700 MHz broadband networks. Since the 700 MHz D-Block shares the same 3GPP LTE band-class as the public safety broadband spectrum, commercial networks utilizing 700 MHz D-block spectrum are candidates for providing this capability to public safety devices operating in the dedicated 700 MHz public safety band, although the use of other commercial 700 MHz broadband networks by public safety is not precluded. Furthermore, just as today public safety agencies make extensive and effective use of commercial networks for data services and non-mission critical voice, it is expected that public safety will make use of commercial 700 MHz broadband networks for non-emergency communication needs as appropriate.

Several comments filed with the FCC have strongly criticized the effectiveness of this approach to provide additional broadband bandwidth to public safety during emergency situations, when dedicated public safety networks (such as the 700 MHz public safety broadband network), as well as commercial networks are stressed to their capacity limits. The critiques focus on the assertions that: a) there are insufficient levels of priority within the LTE standard available to public safety users who “roam” onto commercial networks; specifically, mission-critical communications will not be able to be distinguished from more routine public safety communications (e.g. “life at stake” vs. “cat in a tree”); b) if the commercial system is at 100% of capacity with lower priority commercial users, there is no mechanism within LTE to allow public safety users immediate access during emergencies; c) during periods of high communication demand, the commercial network access

[44] *See McEwen Ex Parte* at p. 5.

channel will become saturated, and public safety emergency users access requests will not be able to be received and processed. The critiques cite examples when the aforementioned scenarios occurred on actual systems.

Analysis of the priority and access methods in the LTE standard as shown below, however, reveals that there are no technical impediments to providing public safety users immediate access to commercial networks during periods when the network is at capacity. With an appropriate FCC regulatory framework that would require sharing of spectrum during times of emergency, a robust system that serves both public safety and commercial users can be realized.

3.1 Basic LTE Quality of Service (Priority) Mechanisms

The LTE/SAE standard that is proposed for networks deployed in the 700 MHz band is based on an all-IP (internet protocol) end-to-end architecture. Due to the packet-based transport method in LTE, ongoing packet streams can be slowed or delayed "on-the-fly" to accommodate higher priority streams during emergency situations. This capability is fundamentally different than the situation in 2G cellular networks where ongoing circuit-switched connections cannot be interrupted once established. Commenters on the NBP and *FCC Whitepaper* who have cited cellular networks inability to accommodate higher priority traffic during congestion periods have based their observations on the older circuit-switched voice network technology, not LTE.

Correspondingly, as part of the 3GPP Release 8 family of LTE standards specification, a rich set of mechanisms to control user service and network bandwidth have been included. These mechanisms enable networks to be provisioned to prioritize many different types of packet streams, gracefully reduce QoS (Quality of Service) for low priority users during periods of system congestion, and offer differentiated Quality of Service treatments that are appropriate for a broad range of applications. There exists a rich collection of control mechanisms for QoS assurance in LTE networks that can be applied to commercial, dedicated public safety, and mixed commercial/public safety networks.

The following mechanisms, taken from the LTE standards specs, provide a synopsis of the key priority/QoS concepts embodied in LTE. More detailed explanations can be found in the cited standards document(s) themselves. The basic mechanisms available for exploitation in a system design for a shared commercial/public safety user network include: access classes; guaranteed bit rate bearers; aggregated maximum bit rate; Quality-of-Service Class Identifier (QCI); RAC (Radio Admission Control), and Allocation Retention and Priority (ARP).

A brief description of these mechanisms is provided below:

- Access Classes – In LTE, each user equipment (UE) device belongs to an Access (priority) Class in the range 0-9. However, some UEs may belong to one or more high-priority Access Classes, in the range 11-15, that are reserved for specific uses (e.g. security services, public utilities, emergency services, mobile network operations staff etc.). Access barring (or cell access restriction) is performed during connection establishment and provides a means to control the load originated by UE-originated traffic. At times of an emergency incident, the mechanism can be invoked to control what types of devices may access the network: for example, only public safety devices with access classes 11-15 may be allowed, preventing commercial users from blocking the access channel. Access class restrictions might also be needed to limit the number of possible UEs using the Random Access Channel (RACH.)

- Bearers Classifications. In LTE, there are five basic bearer classifications that can be used to provide different grade of service for different user categories such as public safety. These are: Guaranteed Bit Rate – GBR; Maximum Bit Rate – MBR; Non-GBR; Default Bearer; and Dedicated Bearer. GBR is a minimum bit rate requested by an application. In LTE, minimum GBR bearers and non-GBR bearers may be provided. Minimum GBR bearers are typically used for applications like Voice over Internet Protocol (VoIP), with an associated GBR value; higher bit rates can be allowed if resources are available. Non-GBR bearers do not guarantee any particular bit rate, and are typically used for applications as web-browsing. During provisioning of public safety users for access to the commercial LTE network, appropriate bearer classifications can be decided for the public safety users to provide the necessary performance. Additionally, a UE may have an associated Aggregated Maximum Bit Rate – AMBR (UE-AMBR) indicating the maximum total of its non-guaranteed flows.

- Aggregated Maximum Bit Rate – AMBR (UE-AMBR and PDN-AMBR), for a specific UE and PDN (external Packet Data Network), respectively.

- QoS Class Identifier (QCI) [45] – QCI is a parameter of the QoS profile of an Evolved Packet System (EPS) bearer in LTE. It is a scalar value and used as a reference to access node-specific parameters that control bearer level packet forwarding treatment. Examples of such parameters include: scheduling weights, admission thresholds, queue management thresholds etc. These parameters are pre-configured by the operator owning the base site. During public safety user authorization, bearers with appropriate QCI can be assigned to provide the necessary priority over non-public safety users. Each Service Data Flow (SDF) is associated with one and only one QoS Class Identifier (QCI). For each SDF, the service level QoS parameters are QCI, ARP, GBR, and MBR. A Table of Standardized QCI characteristics is shown below.

Standardized QCI characteristics [Tabel 6.1.7 of TS 23.203 V9.3.0]

QCI	Resource Type	Priority	Packet Delay Budget	Packet Error Loss Rate	Example Services
1	GBR	2	100 ms	10^{-2}	Conversational Voice
2		4	150 ms	10^{-3}	Conversational Video (Live Streaming)
3		3	50 ms	10^{-3}	Real Time Gaming
4		5	300 ms	10^{-6}	Non-Conversational Video (Buffered Streaming)
5	Non-GBR	1	100 ms	10^{-6}	IMS Signalling
6		6	300 ms	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		7	100 ms	10^{-3}	Voice, Video (Live Streaming), Interactive Gaming
8		8	300 ms	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video etc)
9		9			Default bearer for non-privileged users (no packet delay or loss constraints)

- Radio Admission Control (RAC). The RAC function is located in the LTE base site and controls admission or rejection of new radio bearer (communication channel) establishment requests. The goal of the RAC is to maximize radio resource utilization while ensuring that the required Quality of Service (QoS) is achieved for sessions which are already established. RAC can take into account the overall resource situation in E-UTRAN (LTE radio access network), the QoS requirements, the priority levels, the provided QoS of in-progress sessions and the QoS requirements of new radio bearer requests.[46]

[45] QoS is a descriptor of the level of performance provided in transmission of data. Typical QoS metrics include bit rate, delay, bit/block error rate, maximum blocking probability and outage probability. QoS guarantees are especially important for real-time streaming applications, such as streaming video or Voice over IP (VoIP) since these are often delay-sensitive.

[46] *See* 3GPP TS36.300, Section 16.1.2.

The RAC function could be used in times of emergency incidents to reject bearer establishment requests that are: a) resource intensive (e.g. video streaming or uploads) or b) require resource guarantees (e.g. GBR requests) or c) deemed limited value by the operator. The operator may use the RAC function and allow or disallow bearer requests for low priority (non Public Safety) users with low bandwidth and/or high value requirements.

- Allocation Retention and Priority (ARP). ARP is a parameter of the QoS profile of an LTE Evolved Packet System bearer. It is designed to facilitate decisions as to whether a bearer establishment/ modification request can be accepted. It provides information about the priority level, the pre-emption capability and the pre-emption vulnerability. The priority level defines the relative importance of a resource request. This allows deciding whether a bearer establishment or modification request can be accepted or needs to be rejected in case of resource limitations (typically used for admission control of GBR traffic). It can also be used to decide which existing bearers to pre-empt during resource limitations.

  The range of the ARP priority level is 1 to 15 with 1 as the highest level of priority. The pre-emption capability information defines whether an existing service data flow can get resources that were already assigned to another service data flow with a lower priority level. The pre-emption vulnerability information defines whether a service data flow can lose the resources assigned to it in order to admit a service data flow with higher priority level. The pre-emption capability and the pre-emption vulnerability can be either set to 'yes' or 'no'.

  ARP is a key mechanism available in LTE for facilitating the use of a congested network by public safety users in times of emergency.

3.2 Additional Mechanisms for Giving Priority to Public Safety Users on Commercial LTE networks

3.2.1 Policy and Charging Rules Function (PCRF).[47]

A key component of a LTE/SAE core network is a Policy and Charging Rules Function (PCRF). This allows the packets belonging to public safety users to be given preferential treatment over those belonging to commercial users in times of emergency. Its major functions include: dynamic bearer and bandwidth control, charging rule provisioning and in certain cases, lawful intercept control. The PCRF provides a *single place* where the operator can implement business rules to dynamically control usage of the network and how much to charge for particular services. In a commercial network, a common use of the PCRF is to temporarily reduce bandwidth during peak hours for users that go over their monthly usage quota in order to reduce the overall peak demand that drives network capital expenditures. At the same time, the application specific control made possible by the PCRF could also provide full bandwidth at a different charge for those premium services that are paid for outside of the basic data service. Examples of policy rules that an operator may optionally choose to implement include:

• Allocation and retention policies that can implement prioritization of certain flows, including pre-emption capabilities and vulnerabilities.

• Aggregated maximum bit rate per APN (access point name) that is the subscribed and authorized bandwidth maximums for an APN as a whole.

• Authorization of basic default bearer QoS parameters for the default best-effort data service flow. This function will be useful due to the very high bandwidth that can be achieved by LTE and the likely multiple tiers of service that will be used.

[47] *See* 3GPP TS 23.203, Policy and Charging Control Architecture (Release 8).

• Time of day based rules — situations such as the activation and deactivation of rules based on time of day and time-based session revalidation. This is particularly useful as operators have realized that session treatment should vary during peak and off peak hours in order to maximum throughput while minimizing costly network congestion.

The role of PCRF control function in the LTE EPC (Evolved Packet Core) can be augmented with additional policy rules governing how commercial operator may handle commercial traffic (in relation to public safety traffic) during times of emergency. Additional policy rules will effectively reduce bandwidth available to the commercial operator and make them available for public safety use on an as needed basis.

The functionality of PCRF is general and flexible to accommodate additional operator specified policy rules that can be invoked only in specific emergency situations. For instance, during an emergency situation, an operator could potentially incorporate policy rules that inhibit commercial user uploading or downloading bandwidth hungry video streams or other resource intensive applications. New limits on how much data the user can transfer may be enforced by appropriately defined policy rules. Such emergency situation policy rules remain in effect only for the duration of the emergency. When the emergency situation clears up, the commercial operator will revert back to rules that are applicable for normal conditions.

Policy and Charging Control functionality encompasses a Policy Control process whereby the PCRF indicates to the PCEF (Policy Control Enforcing Function) how to control the bearer traffic. It includes QoS control and/or gating control on a per service data flow basis. Gating control is the process of blocking or allowing packets, belonging to a service data flow, to pass through to a desired endpoint. An operator has the ability to control each service offered by the LTE network. For a controlled service, the complete PCC (Policy and Charging Control) rule information, including service data flow filter information, is available in the PCRF through configuration.

A specific user data flow carried through the PCEF is an IP packet flow. A PCC decision consists of PCC rules and bearer attributes, which is provided by the PCRF to the PCEF for policy and charging control.

A PCC rule is a set of information that enables the detection of a service data flow and provides parameters for policy control and/or charging control.

A QoS rule is a set of information enabling the detection of a service data flow and defining its associated QoS parameters. QoS control per service data flow allows the PCC architecture to provide the PCEF with the authorized QoS to be enforced for each specific service data flow. Criteria such as the QoS subscription information may be used together with policy rules such as, service-based, subscription-based, or pre-defined PCRF internal policies to derive the authorized QoS to be enforced for a service data flow. A pre-defined PCC Rule is one that has been provisioned directly into the PCEF by the operator. The following figure specifies PCC architecture for roaming with PCEF in a visited network.[48]

[48] *See* 3GPP TS 23.203.

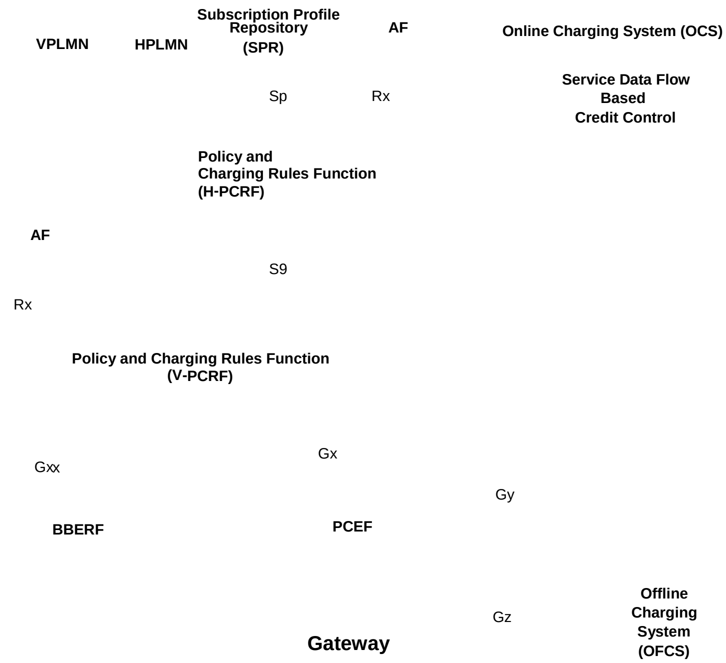

Figure: PCC (Policy and Charging Control) architecture for roaming with PCEF in visited network

3.2.2 Ensuring Control Channel Capacity for Public Safety Users

When an emergency incident occurs and public safety users are seeking to roam onto a commercial network, it is required not only to limit the low priority users from accessing the affected base stations, but also to ensure that all public safety users who want to gain access and establish radio connection through the base station are able to do so. This requires appropriate configuration and sizing of the LTE Random Access Channel (RACH). RACH is a transport channel used for access to the network when a UE does not have accurate uplink timing synchronization, or when the UE does not have any allocated uplink transmission resource. The RACH is normally contention-based, which may result in collisions between UEs.[49] It is important to ensure the control channel has adequate capacity to allow most or all PS users to get in through the RACH channel. This can be done by dimensioning the RACH channel size suitably so that PS users are not locked out due to insufficient size of RACH channel.

The random access procedure in LTE is performed at any of the following five events: i) initial access of an idle mobile; ii) reestablishment after radio link failure; iii) handover to a different cell; iv) downlink data transmission to a mobile, which is out of time-synchronization; and v) uplink data transmission from an out-of-synch mobile. In all cases, one objective is to establish uplink time synchronization, while in some it also provides the means for the mobile to notify the network about its presence and for network to give the mobile initial access. The possibility of a collision, or contention, between different users' access attempts needs to be handled (contention-based procedure). Prior to sending the random access preamble, the mobile performs cell selection, if necessary, and establishes downlink synchronization. The mobile acquires broadcasted information about the random access resources and procedure configuration.

[49] *See* 3GPP TS 36.321: E-UTRA MAC Protocol Specification.

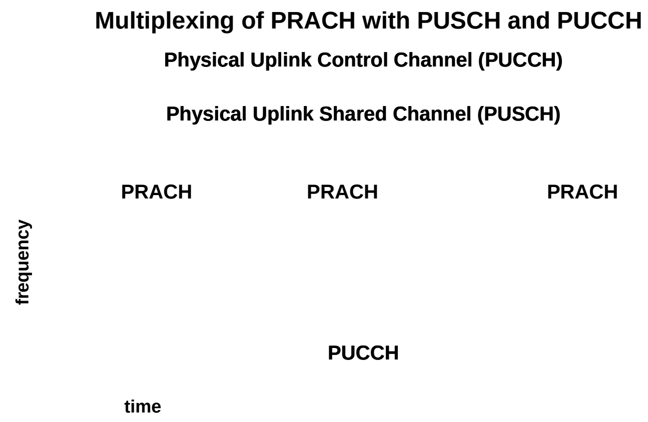

Figure: Multiplexing of PRACH with PUSCH and PUCCH

The random access preamble part of the random access procedure is mapped at the physical layer onto the PRACH (Physical Random Access Channel). The PRACH is time- and frequency-multiplexed with PUCCH (Physical Uplink Control Channel) and PUSCH (Physical Uplink Shared Channel). PRACH time-frequency resources are semi-statically allocated within the PUSCH region, and repeat periodically. The possibility of collisions can be greatly reduced among public safety users if at times of emergency situation, the PRACH region is increased suitably (while PUSCH is decreased by the corresponding amount) so that the collision probability among public safety users attempting to get successfully past the RACH process is kept below a design threshold.

It is worth noting that in the example cited for earlier systems,[50] in which public safety users were (unsuccessfully) trying to access a commercial network (2G/3G); those networks were unaware or unable to adjust themselves for an emergency situation. However, going forward, as both the commercial (D-Block) and public safety LTE-based networks are being designed, it is possible to avoid control channel congestion among public safety users by prompt awareness and adaptation to an emergency situation.

3.3 An Approach for Roaming and Priority Access between Dedicated Public Safety and Commercial Broadband Networks

In this section, a conceptual description is given of how interoperability between a dedicated public safety network and commercial broadband networks could be provided to give public safety users additional bandwidth when needed during emergency situations.

The overall concept is that public safety users can roam with priority access into other broadband networks when demand for bandwidth exceeds the bandwidth available on the public safety broadband network. A commercial broadband network will use the D-Block under normal conditions but will yield capacity to high priority public safety users when the situation demands it.

The extent of additional bandwidth needed in an emergency situation is primarily dependent on the severity of the emergency crisis, as well as the bursty nature of data and video applications that will be needed by the public safety users. The mechanism of roaming and priority access can also be used for roaming onto other compatible networks (in the 700 MHz band or other bands) if the public safety user device is designed to operate in these bands and there is a cooperative agreement in place between public safety and commercial network operators.

The following basic concepts and mechanisms available in LTE will be used to facilitate roaming and priority access:

[50] *See NYC Requirements at p. 6, Cory Lidle incident.*

- LTE supports the control of cell selection and reselection procedures based on information on cell status and cell reservations at a given time. Cell barring can be invoked if an UE is to be denied ability to select/re-select a cell (under emergency or any other operator determined condition). A UE may be allowed to reselect another cell according to specific rules. In the event of an emergency an operator may only allow public safety UE to perform cell selection. This is an extreme form of adjusting to an emergency situation. Other less stringent rules may be at applied by the commercial operator.

- In a special reserved state, an operator reserves a cell for operator activities such as maintenance, special events, etc. Only specific access classes are allowed for cell selection/re-selection. The public safety users can be added to the list of allowed access classes.

- An access barring list is a set of devices or subscribers that are inhibited from requesting or using systems or services. In times of emergency, the commercial operator can *temporarily* add low-priority users to the list of inhibited users to prevent blocking and overloading. Temporarily disallowing the low-priority users reduces their competition with PS users for bandwidth during emergency incidents.

- Access control using access classes can be used in a variety of ways. The commercial operator can prevent devices of its users from initiating an RRC connection in some or all cells during times of an overload situation or during times of emergency. The commercial operator can reserve a specific access class exclusively for PS users and allow only this class of users into the system.

In summary an LTE/SAE based Enhanced Packet System that provides dedicated Public Safety service, coupled with a D-Block commercial network, has the rich and flexible arsenal of QoS and resource management mechanisms needed to give priority capability to PS users during times of emergency incidents. Regarding the commercial system users, even in the worst emergency incident, a certain minimum amount of bandwidth can be made available for necessary emergency communication needs of the commercial users (e.g. 911 services)

3.4 Prior Implementations of Priority Access without Preemption - Voice

The QoS and priority mechanisms of LTE are rich enough and provide the means to construct commercial broadband networks that give preferential treatment to public safety traffic via priority access, without pre-emption of ongoing traffic, when used in conjunction with a dedicated public safety broadband network. Harmonious co-existence of public safety voice users taking advantage of PSTN networks during times of emergency has been built and supported by many of the wireless carriers in the U.S. There are precedents to the use of non-preemptive priority schemes in existing narrowband public safety systems. These include the emergency services – a) Government Emergency Telecommunications Service (GETS)[51] and b) Wireless Priority Service.[52]

GETS was designed for use when national security and emergency preparedness (NS/EP) personnel are unable to complete emergency calls through their regular telecommunications means. GETS uses a calling card to provide its users with a higher probability of call completion during emergencies that cause congestion or network outages. GETS features are implemented as software enhancements to the telephone switches throughout the Public Switched Telephone Network (PSTN). GETS users receive emergency access and specialized processing in local and long distance telephone networks.

Some of the key features of GETS include:

[51] *See* Government Emergency Telecommunications Service, *available at* http://gets.ncs.gov/docs/GETS%20Fact%20Sheet.pdf.

[52] *See* Wireless Priority Service, *available at* http://wps.ncs.gov/program_info.html.

- Access Authorization

- Enhanced Routing of GETS calls despite numerous switch failures in the PSTN

- Ubiquitous Coverage: GETS is supported by the major PSTN service providers, providing nationwide connectivity

- Priority Treatment of GETS users
  - Unique identifiers carried across the signaling network and used to trigger priority features such as trunk queuing
  - Priority within the signaling network
  - Exemption from restrictive network management controls used to reduce network congestion

The FCC issued an order in July 2000 allowing cellular providers to offer wireless priority services to authorized personnel to meet national communication needs. Wireless Priority Service (WPS) is a priority calling capability that greatly increases the probability of call completion during a national security and emergency preparedness event while using their cellular phone. To make a WPS call, the user must first have the WPS feature added to their cellular service. Once established, the caller can dial *272 plus the destination telephone number to place an emergency wireless call. WPS users are recommended to also have a GETS card. WPS is an add-on feature subscribed on a per-cell phone basis that works with existing cell phones in WPS enabled cellular networks; no special phones are required. WPS provides priority for emergency calls through a combination of special cellular network features and the same “High Probability of Completion” features used by Government Emergency Telecommunication Service (GETS).

- *Originating Radio Channel Priority:* WPS addresses congestion in the local radio access channel (or cell), which is often the reason that cellular calls cannot be made during heavy calling periods or when damage to network infrastructure occurs. WPS automatically provides priority access to local radio channels, placing WPS calls in queue for the next available channel if a channel is not immediately available. Originating Radio Channel Priority requires WPS feature activation on the calling cellular phone. WPS calls do not preempt calls in progress nor will WPS users monopolize all available cellular resources.

- *High Probability of Completion Features*: When a radio access channel becomes available and the call proceeds, WPS calls are assigned a unique “NS/EP” call marking by the cellular network switching equipment. This marking triggers industry standard High Probability of Completion (HPC) features residing in most U.S. telecommunications networks as calls are routed from the originating cell to the called cellular or landline phone. These HPC features significantly increase the probability of call completion should the call encounter network congestion or blockage beyond the originating cell. Thus, WPS calls receive similar “across the network” priority as GETS calls without having to dial the GETS access number and PIN.

- *Terminating Radio Channel Priority:* Incoming WPS (and GETS) calls to cell phones served by WPS enabled cellular networks automatically receive priority access to local radio channels, placing incoming GETS and WPS calls in queue for the next available channel if a channel is not immediately available. Terminating Radio Channel Priority does NOT require the called cellular phone to be subscribed to WPS. Incoming GETS and WPS calls do not preempt cellular calls in progress nor will they monopolize all available cellular resources.

Extensions to the above mechanisms designed for circuit switched, voice calls are also possible for public safety broadband networks working in conjunction with commercial broadband networks. These extensions are discussed in the next section.

3.5 Necessity for Additional Work – Packet and Broadband Networks

It is clear from the description of the capabilities in the LTE standard described in Section 3.3 above that a large number of mechanisms are available to give public safety users the level of priority access they require when operating (roaming) on commercial networks. In order to describe the details of how these mechanisms will work in specific situations, extensions to the voice-oriented GETS and WPS procedures described immediately above are required to accommodate the packet nature of LTE. To respond to this need, the Next Generation Government Emergency Access Telecommunication Service (NGN GETS) initiative was initiated and has completed its Phase 1 work.[53] The NGN GETS charter is to create a priority access system for interoperability between packet networks such as a commercial LTE network, and public safety networks using LTE. In order to incorporate these procedures into the 3GPP standard suite, a work item on enhancements for multimedia priority service is currently underway.[54] This is in contrast to the critics of the FCC Whitepaper who state that no such activity exists.

In the regulatory sphere, the experience gained with designing rules for the GETS, WPS and NGN GETS services should be leveraged by the FCC and the National Communications System (NCS) to develop an agreed on system of priority network access and traffic routing policies for national security/emergency preparedness (NS/EP) users on broadband communications networks. Commercial D-Block and Public Safety interoperability trials would be valuable in assessing and validating the effectiveness of the mechanisms decided on, and refining the prioritization and interworking approaches and policies.

4. Interference

4.1 Introduction

The National Broadband Plan recommends the auctioning of the 700 MHz D-Block for commercial use, and the utilization of the immediately adjacent 700 MHz public safety broadband spectrum block for the deployment of a nationwide broadband network. LTE technology, developed as a 4G (fourth generation cellular) standard for commercial networks, has been endorsed by the public safety community in the United States for deployment in the 700 MHz band, and commercial providers plan to utilize LTE technology in the D-Block.[55] Both networks would use the same LTE design principles, and the LTE physical layer specification has been designed to allow different networks to operate in adjacent spectrum with no guard band.[56]

4.2 Previous Comments Filed

Comments have been filed with the FCC alleging that unacceptable interference in public safety broadband user equipment will be generated by base site transmitters in the commercial D-Block, causing coverage holes unacceptable to public safety.[57] The comments state that the 3GPP LTE technical analysis used to confirm acceptable performance for LTE systems operating in adjacent spectrum blocks without a guard band is inadequate and does not use the correct criteria for assessing acceptable performance for public safety. To further justify this conclusion, RF system simulation results are presented. In one simulation, where cell sizes of the commercial D-Block and public safety networks are the same, but where the commercial sites and public safety sites are not co-located, the results show coverage outage levels as high as 8%. Another system simulation utilizes a public safety site layout with a larger cell size (fewer base sites than the commercial

[53] *See Internet Protocol Multimedia Subsystem Core Network Industry Requirements for Next Generation Network Government Emergency Telecommunications Service*, Voice Service – Issue 1.0 (December 2007), *and Long Term Evolution Access Network Industry Requirements for Next Generation Network Government Emergency Telecommunications Service*, Issue 1.0 (April 2010).

[54] *See* 3GPP SA2 Work Item 460029 – Feature or Study Item: Enhancements for Multimedia Priority Service.

[55] S*ee* APCO and NENA Endorse LTE as Technology Standard for the Development of Nationwide Broadband Network, (Jun. 9, 2009) *available at* http://www.apcointl.org/new/nena_endorse_lte.php; *and* NPSTC Votes To Endorse LTE Technology for Broadband Network.

[56] *See* 3GPP TS 36.211 ver. 9.1.0.

[57] *See* Letter to Ms. Marlene H. Dortch, Secretary, Federal Communications Commission, from Mr. Robert D. Kubik, Director, Motorola Inc., PS Docket No. 06-150, filed Jul. 2, 2010.

network) and shows even higher outage levels. A separate analysis of the selectivity of practical 700 MHz user device duplexers alleges that the passband is too wide to reject adjacent D-Block base site transmitters.[58]

4.3 Analysis of Previous Comments

4.3.1 Simulation of Effect of Interference

The analysis that follows shows that the previous comments describe unjustified and unrealistic assumptions about D-Block base site placement, and assumptions about public safety cell size that are in conflict with the recommendation of the NBP. Further, there is an insufficient description of the system simulation parameters used to allow independent verification of the results. The conclusion is that the claim of unacceptable levels of coverage outage due to intersystem interference is unproven and unjustified.

The figure below contains the D-Block and public safety broadband base site configuration used in the previous comment's computer simulation to show unacceptable levels of interference.[59] (The left hand side of the diagram is a re-drawing of the site configuration used in the previous analysis, and the right hand side of the figure isolates a cluster of public safety sites from the diagram on the left for closer inspection.) In the simulation reported, the D-Block and public safety cell sizes (base site separations) are identical. In both the left and right hand sides of the figure, a cluster of solid triangles represents the public safety base transmitter site, and a cluster of grey-shaded triangles represents the D-Block sites. In this "idealized" multi-cell configuration, base sites are placed at the intersection of hexagons that tessellate (cover without gaps) the intended geographic coverage area. Public safety user equipment would operate over all regions of the hexagonal grid.

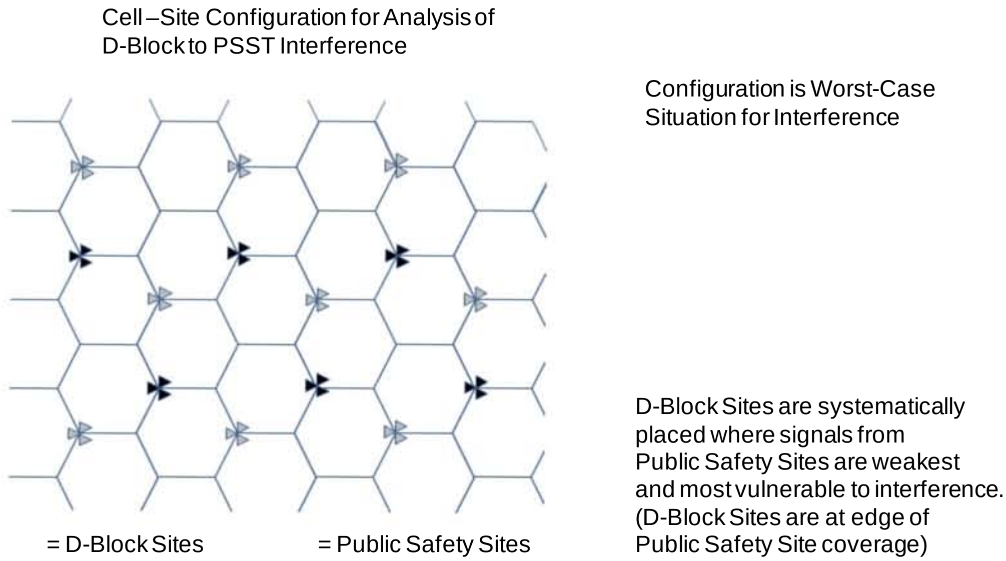

Figure: Analysis of Cell Site Configuration Used in Previous Interference Analysis

First, regarding the assumptions used in the computer simulation, it is not stated whether the RF configuration employs omni-directional or sectored antennas, or what the base site antenna horizontal and vertical gain (tilt) characteristics are. The details and statistics of the RF propagation model are also not described, nor are the assumptions on the end-user application's tolerance to interference stated. All of these elements are essential

[58] *See Motorola Presentation* at *p. 16.*

[59] *See Motorola Presentation* at *pp. 18-19.*

factors in determining an estimate of system performance. As a result the conclusions of the previous analysis cannot be reproduced or validated.

Furthermore, it is noted that the cell site configuration used for the computer simulation, and in particular the choice of the location of the commercial D-Block sites relative to the public safety sites, represents a worst case situation for interference. The reason is that the commercial sites have been placed at the location where the received signals from the public safety sites are weakest, and therefore most vulnerable to interference. This is shown in the right hand side of the figure. While it is valuable and instructive to study worst-case conditions to understand the limits of performance, it is unrealistic to base a potential or actual system layout on a worst-case assumption. Rather, the worst-case study should indicate which base-site configurations are to be *avoided* during layout. For this reason, we reject the assumption in the previous analysis that commercial base sites will be deployed in the exact locations causing the worst interference for public safety. In fact, the NBP and the cost model for the nationwide public safety broadband network[60] recommend that for cost and operational efficiencies, commercial D-Block base sites and 700 MHz public safety broadband network sites should share infrastructure and be co-located whenever possible. The realities of geographic site availability and backhaul availability result in existing sites from current cellular carrier deployments often being in close proximity. It is not uncommon for commercial and public safety base sites to be co-located. The picture below illustrates co-location of cellular and public safety antennas on a 22 story building in Chicago, Illinois.[61]

Picture: Public Safety and Cellular Shared Transmit Site, Chicago, IL 60616

The conclusion is that with more realistic assumptions on commercial site placement, or with co-located base sites, the allegations of unacceptable interference are unsupported. With proper initial system design processes and tools, any potential interference issues can be anticipated and addressed.

4.3.2 Effect of Duplexer Filter

The analysis in the *Motorola Comments* observes that the out-of-band signal rejection characteristics of actual and practical duplexer filters that would be used in public safety user equipment at 700 MHz are inadequate to attenuate adjacent band signals from commercial base sites operating in the D-Block. A graph of the duplexer characteristics is used to illustrate this conclusion. Closer study of this analysis raises important questions about

[60] *See A Broadband Network Cost Model: A Basis for Public Funding Essential to Bringing Nationwide Interoperable Communications to First Responders* (Apr. 2010), *available at* http:// fcc.gov/pshs/docs/ps-bb-cost-model.pdf.

[61] FCC license information and site inspection were used to verify the antennas and equipment at this location.

the assumptions used, and renders the conclusion that an additional guard band is required incorrect. The following discussion summarizes this study.

Interference rejection in radio receivers due to adjacent-band and adjacent channel signals is primarily a function of the receiver selectivity, which in turn is determined by the receiver intermediate-frequency (IF) filter or its baseband equivalent, depending on the receiver architecture. No mention or assumptions of this component's characteristics is given in the previous analysis. On the other hand, the function of the duplex filter in a radio transceiver is primarily to isolate the transmitter and receiver elements within a *single transceiver unit* such as a handheld device. A detailed investigation of LTE receiver chipset specifications, not yet performed, is necessary to ascertain the adjacent band and adjacent channel rejection capabilities of LTE receivers.[62]

A study of the effectiveness of duplex filters and/or receiver selectivity filters to reject adjacent band signals would of necessity include: a) a quantitative, and ideally, a statistical analysis of the range of signal levels to be expected from the interfering source (in this case, the D-Block base transmitter); b) the application of those signal levels to the combination duplex filter/selectivity filter; and c) a determination of the level of the resulting interference signal that can be tolerated based on the error correcting capabilities of the signals sent, and considering the tolerance of the end-user application to errors. For example, the error correcting code scheme used in video transmission allows for a certain level of received bit errors due to interference or noise to be corrected before the video information is presented to the end user. Regarding these requirements for analysis, there is no description of the parameters or assumptions used to reach the conclusions about the effectiveness of the public safety receiver in rejecting interference. For this reason, the previous analysis's allegation that practical duplexer filter characteristics result in unacceptable levels of interference in public safety user equipment is not supported. The open analysis of interference, part of the 3GPP LTE standards activity that supports the deployment of LTE equipment in adjacent bands without a guard band, should be followed.

4.3.3 Current 800 MHz Band Interference Experience

Several comments submitted to the FCC have noted the serious interference issues experienced in the 800 MHz frequency band due to Nextel base site transmissions interfering with public safety user equipment, and reason that this indicates similar serious problems will be experienced in the adjacent Public Safety Broadband Block at 700 MHz if the D-Block is deployed for commercial use.[63] This reasoning is incorrect as explained below.

In the 800 MHz band, a major cause of the interference experienced in public safety user receivers is a result of a) the large number of narrowband digital channels used by Nextel being adjacent or very closely spaced in frequency (interleaved) with the narrowband public safety channels, coupled with b) the large number of Nextel cellular base sites in the coverage area of the public safety system, where the public safety system is operating from a single high-antenna broadcast site. The result is that relatively lower power received public safety signals (due to the longer distance from the broadcast site to the public safety user receiver) are overcome by the signals transmitted from many more, and much closer, Nextel base sites on adjacent and near-adjacent channels. Intermodulation caused by Nextel base sites is also a contributor to the interference.[64] Furthermore, the analog public safety equipment was not designed with the characteristics of the digital Nextel equipment taken into consideration. This is not the situation in the 700 MHz band: both the 700 MHz broadband public safety network and 700 MHz D-Block commercial system will be designed and deployed as multi-cell system designs, with comparable or identical base station antenna heights and transmit powers. Both the public safety network and the commercial D-Block network will use the digital LTE air interface standard, with similar if not identical transceiver components designed for operation in adjacent spectrum bands.

[62] *See e.g.* the overview description *available at* http://www.altair-semi.com/3gpp-lte-chipsets.

[63] *See Seybold Comments, and Motorola Presentation.*

[64] *See* Letter to Mr. Thomas J. Sugrue, Chief Wireless Telecommunications Bureau, Federal Communications Commission, from Robert S. Foosaner, and Lawrence R. Krevor, filed Nov. 21, 2001, ("Eliminating CMRS-Public Safety Interference in the 800 MHz Band and Allocating Additional Spectrum to Meet Critical Public Safety Communication Needs"), *available at* http://wireless.fcc.gov/releases/011121-letter.txt.

4.3.4 D-Block Interference to GPS

Previously submitted comments examine the potential of self-interference generated within user equipment in the commercial D-Block, to a Global Positioning System (GPS) receiver operating in the same unit.[65] The situation arises because the (potential) second harmonics of frequencies at the edge of the D-Block fall within the passband of a GPS receiver. The comments claim that by combining the D-Block with the Public Safety Broadband spectrum, the potential for interference is reduced. A closer examination of the GPS interference situation reveals that there is little difference in the interference potential between the two approaches. Solutions are available to mitigate this type of interference if it is encountered in the user equipment design phase, and the conclusion reached here is that GPS interference potential should not be a decision factor in the allocation of the D-Block to commercial use.

The Global Positioning System (GPS) has a center frequency of 1575.42 MHz, utilizes CDMA modulation, and employs receivers with a nominal bandwidth of 2 MHz. With a GPS receiver passband of approximately 1574.42 to 1576.42 MHz, a commercial D-Block user device transmitter with transmit energy in the region 787.21 to 788.21MHz can potentially generate 2nd harmonics due to transmitter non-linearities that fall in the GPS receiver passband. The relationship of 700 MHz user equipment transmit frequency bands for the upper C, A, D, and Public Safety Broadband Blocks is shown in the figure below. The range of frequencies whose second harmonic falls with the passband of a GPS receiver is indicated.

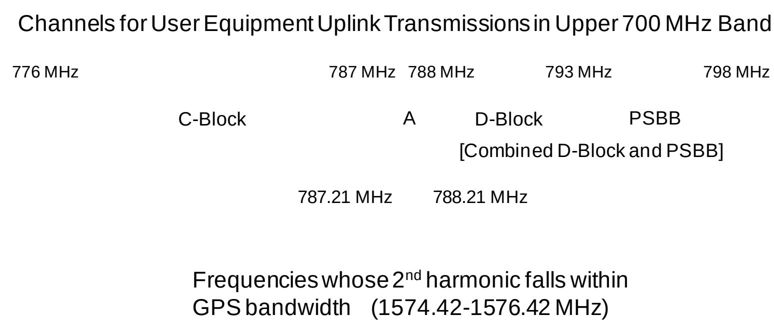

Figure: Analysis of GPS Interference Relationships in 700 MHz Band

From the figure, it can be seen that the extreme lower edge of D-Block allocation, as well as the lower edge of the commenter's proposed combined D-Block and Public Safety Broadband Block (PSBB), fall in the region whose possible second harmonics can interfere with a GPS receiver located in the same device. In practice, the actual occupied bandwidth of transmitters that meet the 3GPP LTE out-of-band emission specifications will be slightly less than the allocated D-Block bandwidth as indicated in the above figure, with the result that there will be relatively lower energy levels at the band edge, with a reduced potential for interference. The edge of the current D-Block, and proposed combined D-Block and Public Safety Broadband Block, are the same. It is expected that there would be a very small difference in the interference potential to GPS devices between 5 MHz D-Block devices, and devices operating in the proposed combined D- and Public Safety Broadband Block.

Furthermore, the reduction and elimination of potential self-interference issues in cell phone transceivers that incorporate GPS receivers has been anticipated, and solution approaches are also known.[66] Second-order harmonics can be minimized in the transmitter design process. Any GPS interference issues that arise in D-Block equipment should be able to be resolved by these and other methods, including the use of a transmit

[65] *See Motorola Presentation at p. 16.*

[66] *See* B. Bernert, *Design Considerations When Integrating GPS into a Cell Phone*, EE TIMES, Mar. 17, 2008, *available at* http://www.eetimes.com/design/analog-design/4018962/Design-considerations-when-integrating-GPS-into-a-cell-phone.

notch filter.[67] Other more sophisticated methods can also be brought to bear.[68] In conclusion, the possibility of D-Block user device transmitter interference into an internal GPS receiver is not an impediment to commercial use of the D-Block as currently specified.

[67] *See* "Interference Mitigation Using Notch Filters," in *Microwave Journal*, June 11, 2007, *available at* http://www.mwjournal.com/News/article.asp?HH_ID=AR_4564.

[68] *See* N.F. Krasner, Reducing Cross-Interference in a Combined GPS Receiver and Communication System, U.S. Pat. No. 6,107,960.

Appendix 1

Profile: Roberson and Associates, LLC

Roberson and Associates, LLC, is a technology and management consulting company with government and commercial customers that provides services in the areas of RF spectrum management, RF measurements and analysis, and technology management. The organization was founded in 2008 and is composed of a group of select individuals with corporate and academic backgrounds from Motorola, Bell Labs, IITRI (now Alion), independent consulting firms, and the Illinois Institute of Technology. Together the organization has over 200 years of the high technology management and technical leadership experience with a strong telecommunications focus.

Profiles: Roberson and Associates, LLC, Staff

Dennis A. Roberson, President and CEO, Roberson and Associates

Mr. Roberson founded Roberson and Associates in 2008, and is concurrently Vice Provost and Research Professor in Computer Science at the Illinois Institute of Technology in Chicago, Illinois. He assists with IIT's technology transfer efforts, the development of new research centers, and technology-based business ventures. Professor Roberson is an active researcher in the wireless networking arena and is a co-founder of IIT's Wireless Network and Communications Research Center (WiNCom). His specific research focus areas include dynamic spectrum access networks, spectrum occupancy, spectrum management, and wireless interference and its mitigation. He currently serves on the governing or advisory boards of several technology-based companies, including four in the telecommunications industry. Prior to IIT, he was EVP and CTO at Motorola. While in this role, he served on the FCC Technology Advisory Committee (TAC). Professor Roberson has had an extensive corporate career including major business and technology responsibilities at IBM, DEC (now part of HP), AT&T, and NCR. Professor Roberson has BS degrees in Electrical Engineering and in Physics from Washington State University and a MSEE degree from Stanford.

Kenneth J. Zdunek, Ph.D. –V.P. and Chief Technology Officer

Dr. Zdunek is Vice President and the Chief Technology Officer of Roberson and Associates. He has 35 years of experience in wireless communications and public safety systems. Concurrently he is a research faculty member in Electrical Engineering at the Illinois Institute of Technology, in Chicago, Illinois, where he conducts research in the area of dynamic spectrum access and efficient spectrum utilization, and teaches a graduate course in wireless communication system design. He is a Fellow of the IEEE, recognized for his leadership in integrating voice and data in wireless networks. Prior to joining Roberson and Associates, he was VP of Networks Research at Motorola, a position he held for 9 years. Dr. Zdunek was awarded Motorola's patent of the year award in 2002 for a voice-data integration approach that is licensed and extensively used in GSM GPRS. He holds 17 other patents, included patents used in public safety trunked systems and cellular and trunked systems roaming. He directed the invention and validation of Nextel's iDEN™ voice-data air interface and IP based roaming approach, and was the principal architect of Motorola's SmartNet™ public safety trunking protocol suite. In the 1990's, he directed a Spectrum Utilization and Public Safety Spectrum Needs Projection submitted to the FCC in support of the 700 MHz spectrum allocation for Public Safety. He was awarded the BSEE and MSEE degrees from Northwestern University, and the Ph.D. EE degree from the Illinois Institute of Technology. He is a registered Professional Engineer in the State of Illinois.

K. S. Natarajan, Ph.D. -Senior Principal Investigator

Dr. Natarajan has 29 years of experience in the research, design, development, trialing, and standardization of communication networks and wireless systems. Prior to joining Roberson and Associates, he was a Fellow of the Technical Staff in Motorola's Wireless Networks division. He has made significant contributions to LTE and WiMAX, having served recently as Motorola's chief technical representative to the LTE System Architecture Evolution Trial Initiative, an industry group that successfully demonstrated key feature and performance attributes of LTE systems. Dr. Natarajan also contributed to the 3GPP LTE/SAE, NGMN (Next Generation Mobile Networks), IEEE 802.11, IEEE 802.16, WiMAX Forum and ITU-T standardization efforts. He was the lead technical architect and principal technical contributor for multiple successful all-IP (internet protocol) network trials with leading Asian operators. He has been recognized as a Motorola Distinguished Innovator and won awards for his creativity and innovation in IP cellular & broadband wireless systems, specifically, the design, standardization & realization of All-IP wireless systems. Before joining Motorola, he was at IBM's Thomas J. Watson Research Center where he initiated and led R&D for IBM's wireless Radio LAN product, and was acknowledged as a major contributor to the IEEE 802.11 standard. Dr. Natarajan holds 36 US patents, and has over 35 refereed papers in conference or journal publications. Recently, he was invited by the White House to evaluate proposals submitted to the BTOP (Broadband Technology Opportunities Program). Dr. Natarajan was awarded the B.Tech. EE degree from the Indian Institute of Technology (Madras), M.E. from the Indian Institute of Science (Bangalore) and the M.S. and Ph.D. degrees in Computer and Information Science from the Ohio State University. He is a Senior Member of the IEEE and a member of the IEEE Communication Society.

Nicolas E. Buris, Ph.D. -Senior Principal Investigator

Dr. Buris is an IEEE Fellow with 24 years of experience in antennas, microwaves, RF propagation and electromagnetics software tool development. Prior to joining Roberson and Associates, he was Director of the Antenna Research Lab at Motorola. He also served on the faculty at the University of Massachusetts at Amherst. He has been a visiting professor at North Carolina State University, a summer faculty fellow at the NASA Langley Research Center, and is a Distinguished Lecturer of the IEEE Antennas and Propagation Society. Dr. Buris received his Diploma in Electrical Engineering from the National Technical University of Athens and his Ph.D. from the North Carolina State University. He holds 6 patents with 7 pending, has published over 40 refereed papers in journals and conferences, and has chaired a couple of Telecommunications Industry Association (TIA) standards committees on antennas and RF exposure.

Edward Porrett –Senior Engineer

Mr. Porrett is an RF electronics engineer with over 35 years of experience in the areas of antenna measurement, RF propagation studies, and radio prototype development and testing. Prior to joining Roberson and Associates, he was a Senior Staff Engineer at Motorola, Inc., Schaumburg IL, where he operated and maintained an outdoor antenna test site, operating at frequencies from 100 MHz to 6 GHz, and serving internal Motorola and external customers. He performed measurements that documented the effective radiation patterns and gain for body-held two-way radios in order to provide parameters for the design of public safety radio systems. He participated in the design and creation of a method for characterizing a building's wall construction to predict its RF propagation loss characteristics. He has been awarded 3 U.S. patents and holds an AAS EET degree from the Michigan Technological University, Houghton, Michigan.